

Fortifications, Fighting-Vehicle Tracks, and Artillery Craters on the Front Lines of the Ukraine War

Erik C. Duncan, Sergii Skakun, Inbal Becker-Reshef





At A Glance

- 3.8 Million Artillery and rocket craters 2/2022-2/2023 ($\pm 0.6m$)
 - 31,000 square kilometers of heavily affected land
- Extending our estimate gives ~ 8.0 million craters since 2022
 - A staggering amount of unexploded bombs

Massive use of unguided
artillery



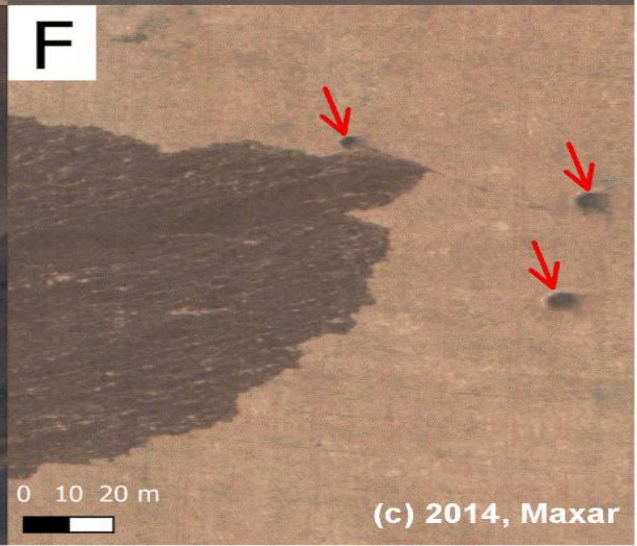
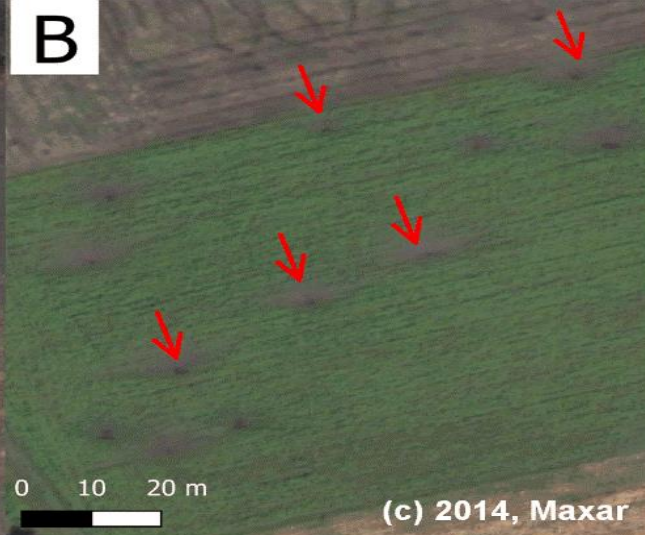
M-46 130mm field gun



BM-21 Grad



Maxar WV3 - 2022





Training A Crater Detection Model



VHR Training
Imagery Selection

Image Preprocessing
Pipeline *



Processed Imagery

18,472 Craters Marked



Crater Locations + VHR Imagery

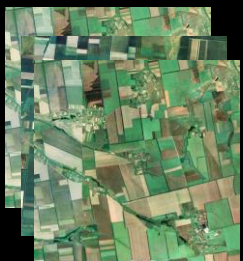
U-Net CNN
Crater-Detection
Model

Mapping With Trained Model



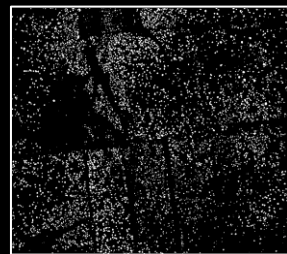
VHR Training
Imagery Selection

Image Preprocessing
Pipeline



Processed Imagery

Apply Model



Binary Detection Masks


Raster Postprocessing *



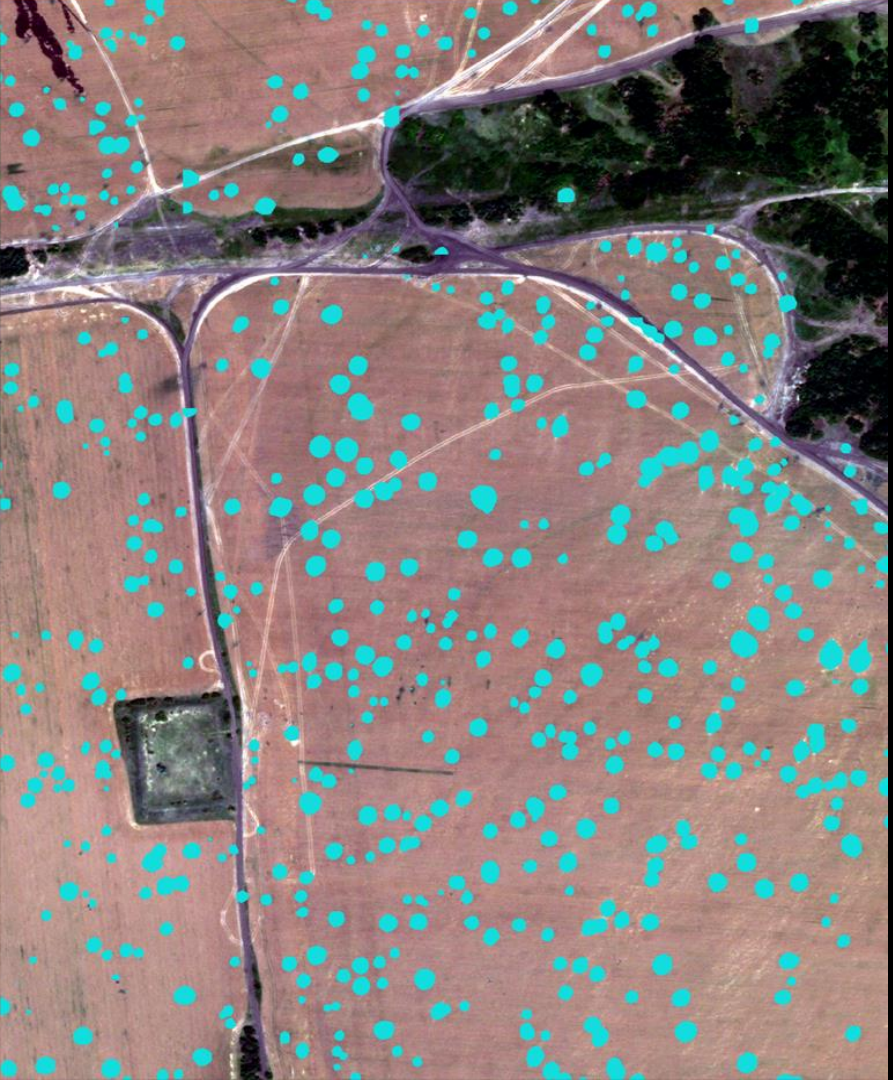


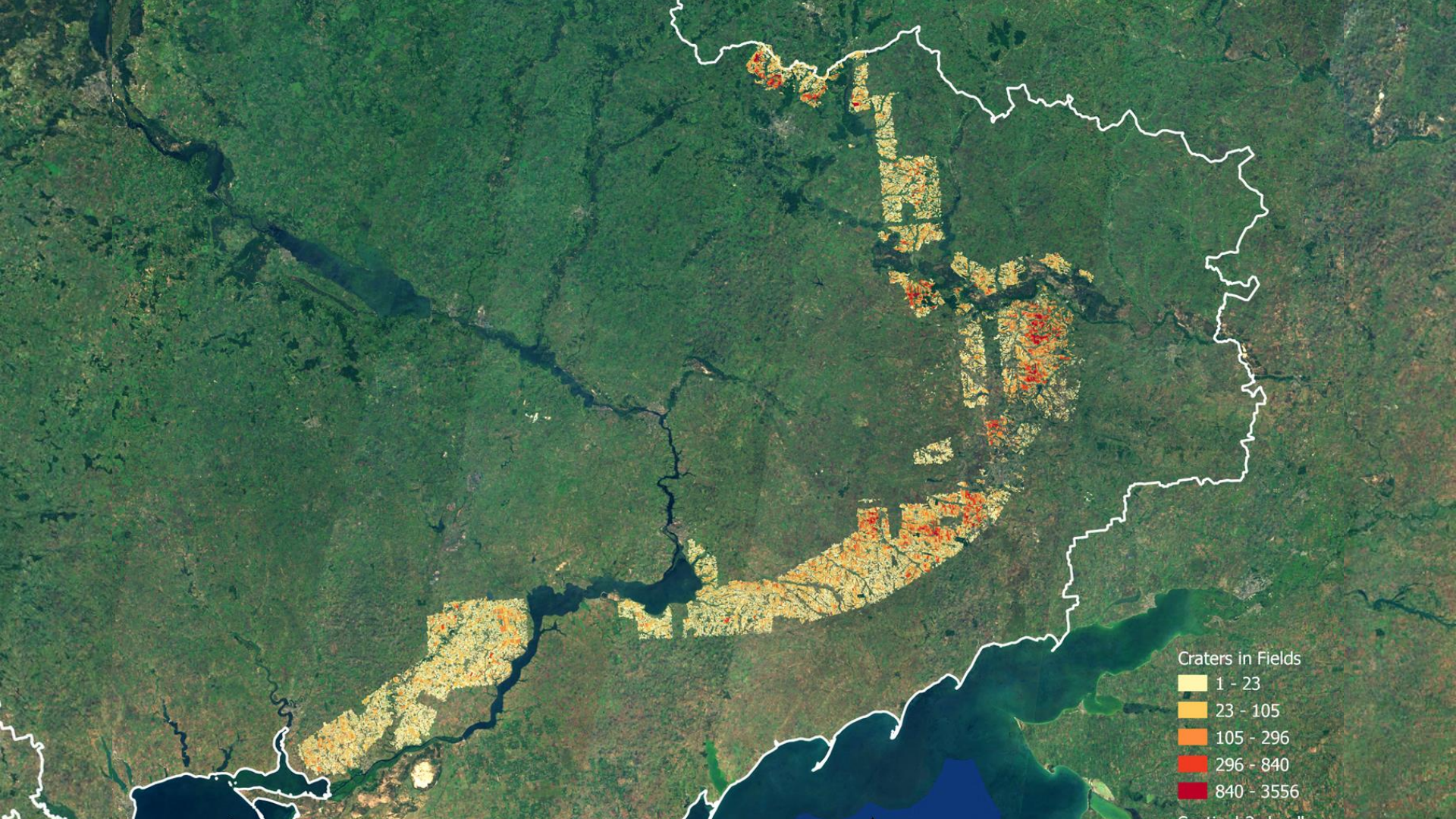
0 75 150 225 300 375 m

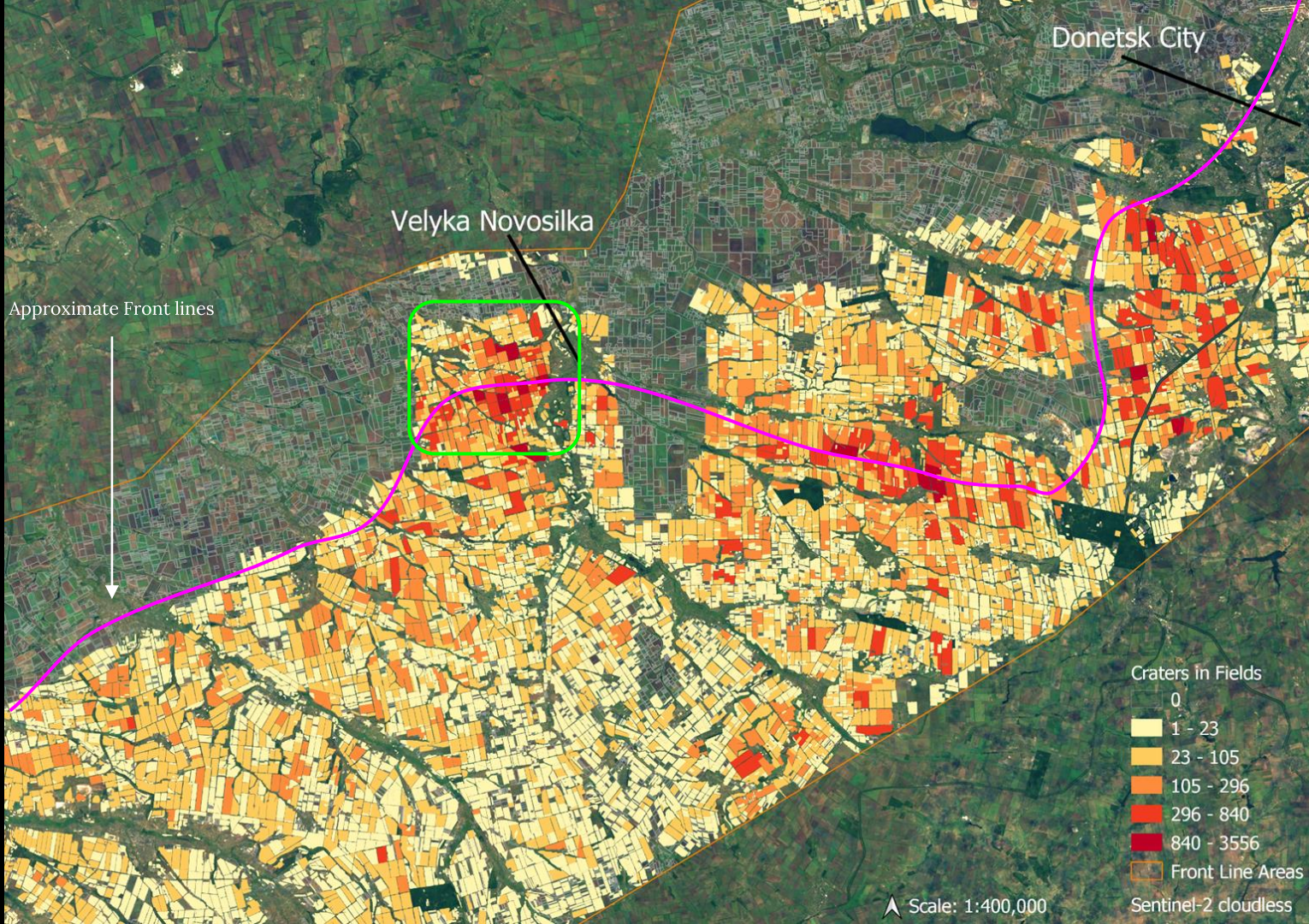
Detected Craters

 Crater Location

Planet Skysat Imagery
2022-07-02

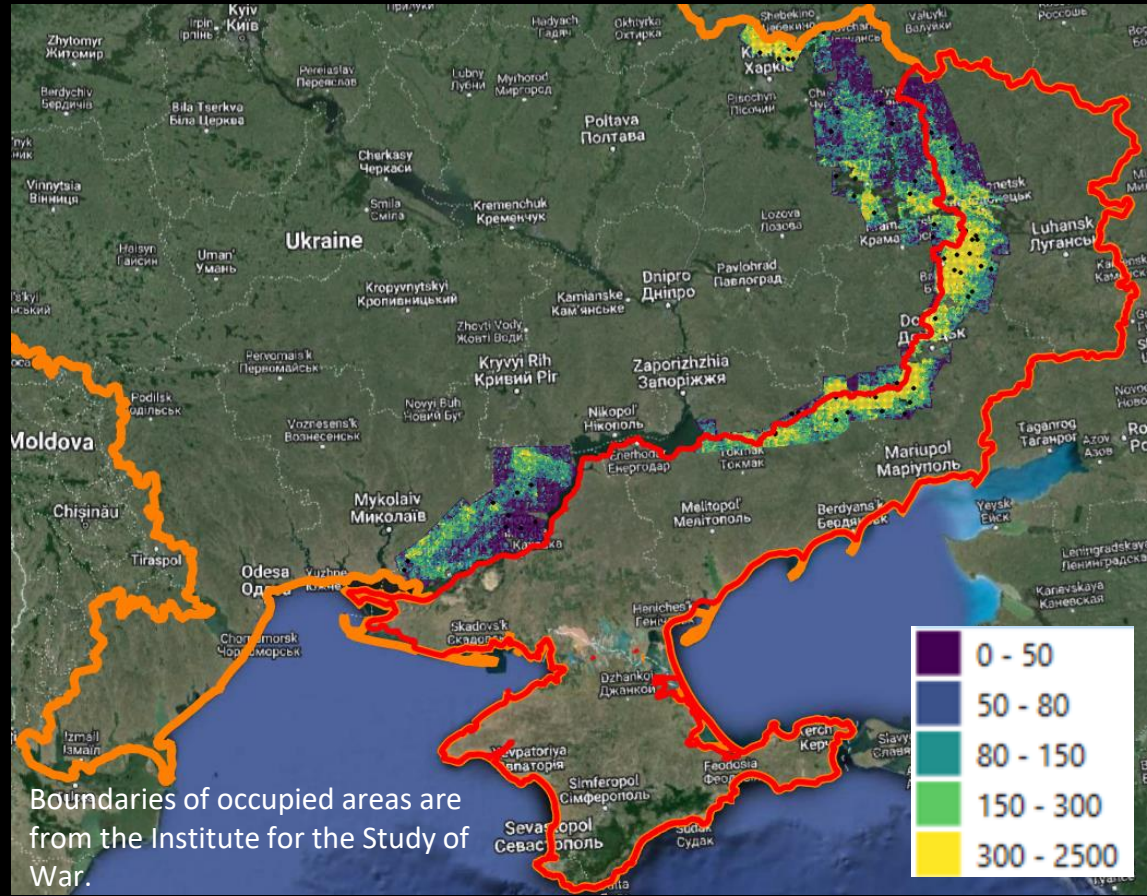


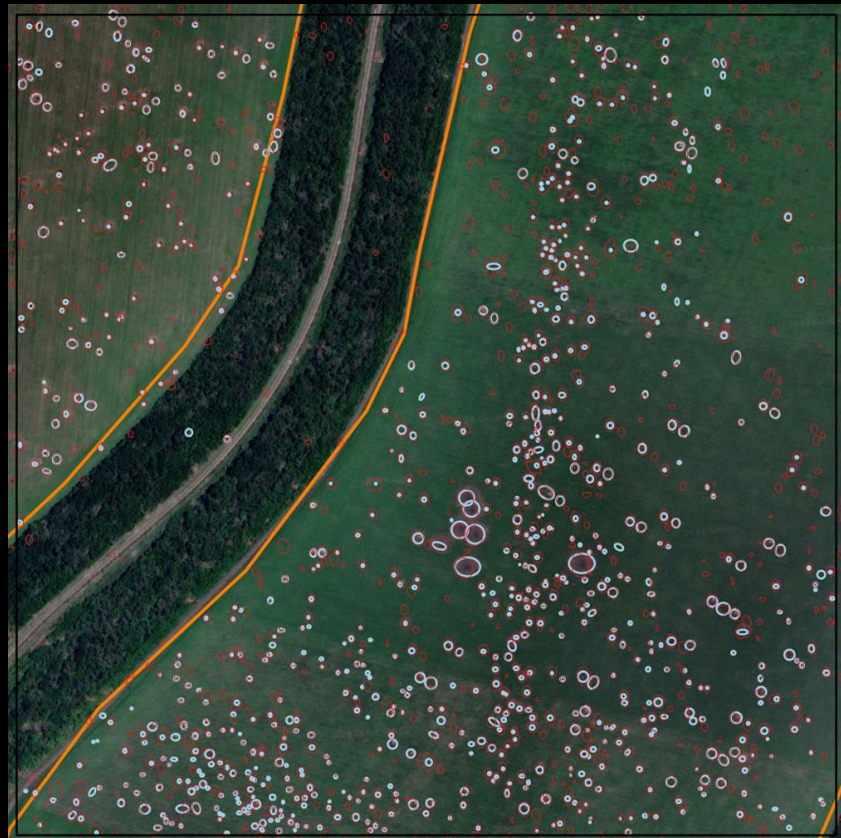
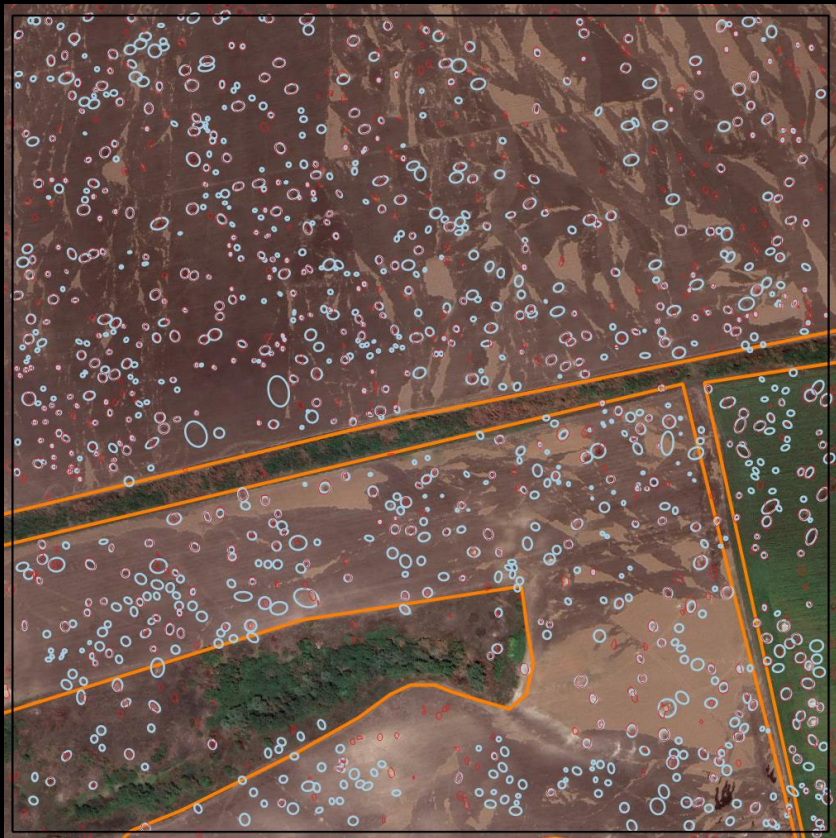




Validation Methodology

- Area split in blocks 1x1 km²
- Population: 31,034 km²
- Sampling design:
 - Sampling unit: 1x1 km²
 - Stratification
 - By # of mapped craters (N_c)
 - Four strata:
 - 1: $N_c < 90$ ($W_1 = 0.43$)
 - 2: $90 \leq N_c < 245$ ($W_2 = 0.34$)
 - 3: $245 \leq N_c < 545$ ($W_3 = 0.17$)
 - 4: $N_c \geq 545$ ($W_4 = 0.06$)
 - Sampling
 - 15 samples in each stratum





○ Satellite-detected ○ Labeled ○ Field boundaries

A July 9, 2014: cultivated



B September 13, 2014: shelled, with craters



C June 6, 2016: abandoned
(can you see any dangers?)



D June 10, 2020: cultivated
(can you see any dangers?)



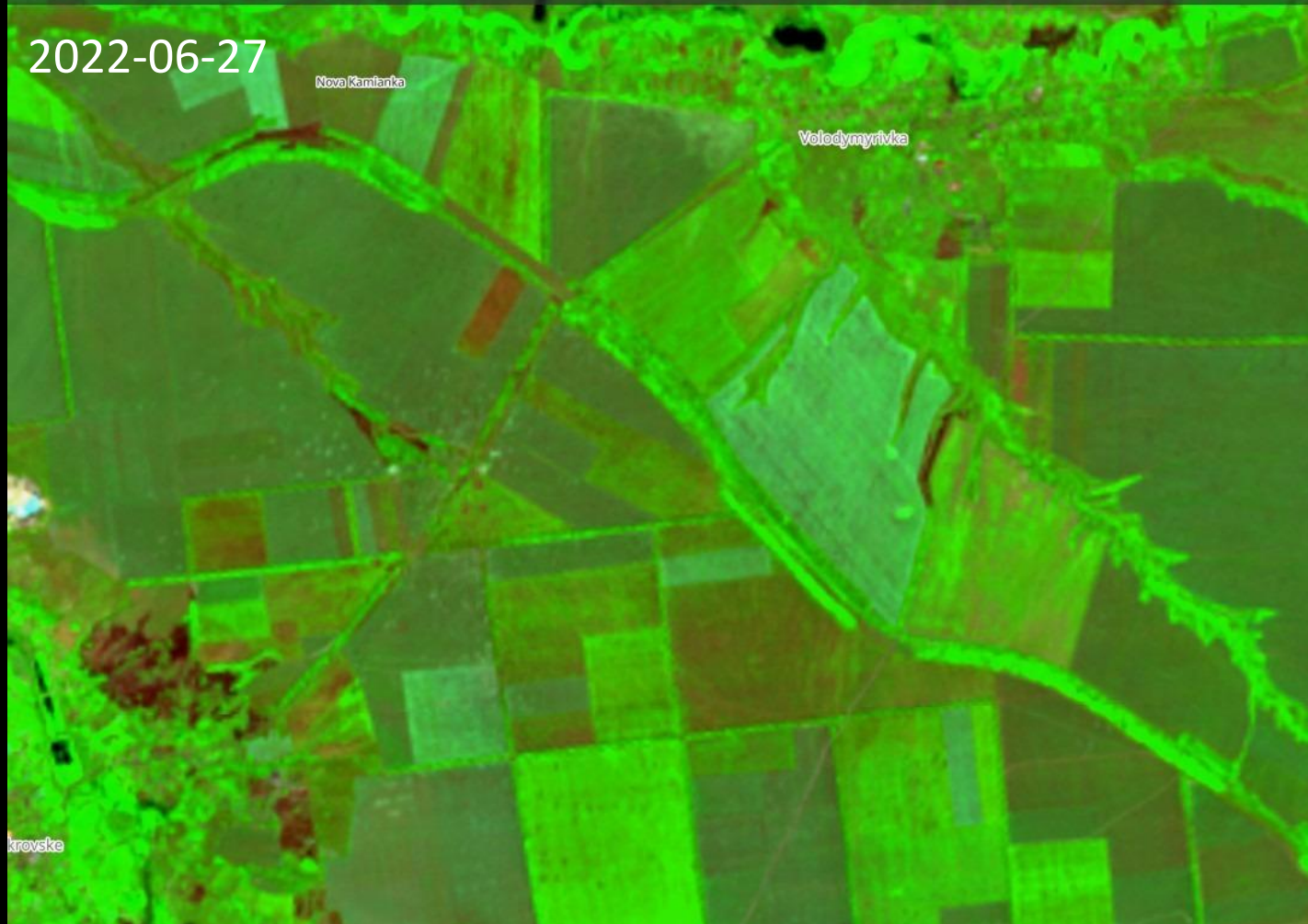
2022-06-27

Nova Kamianka

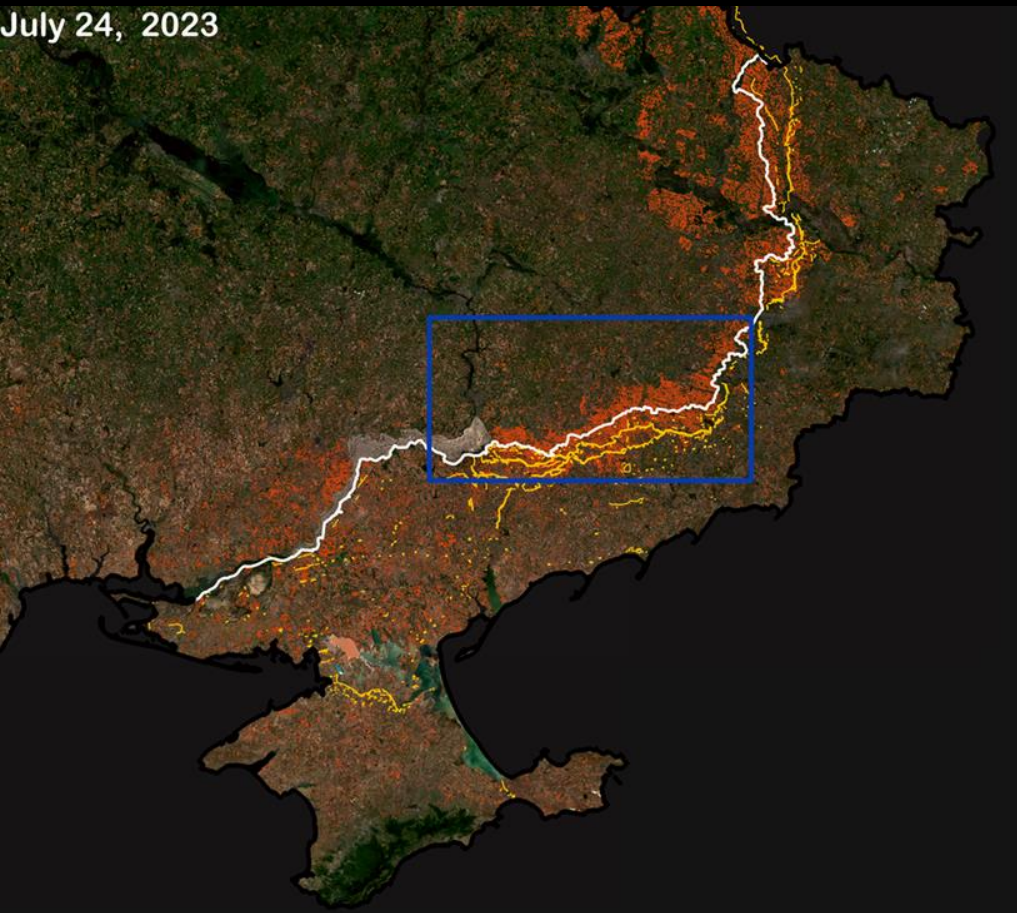
Volodymyrivka

ukrovske

500 m



July 24, 2023



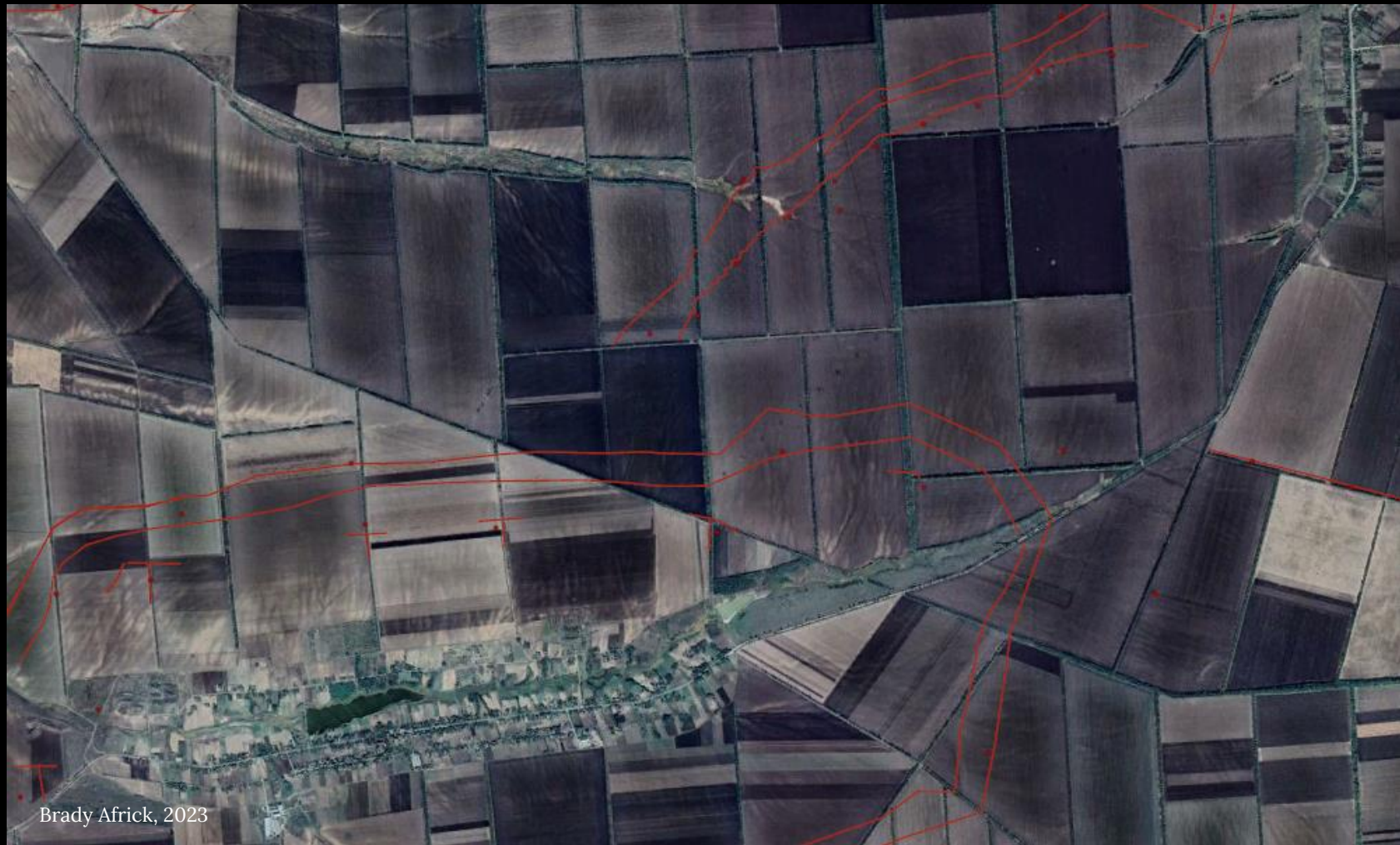
July 24, 2023



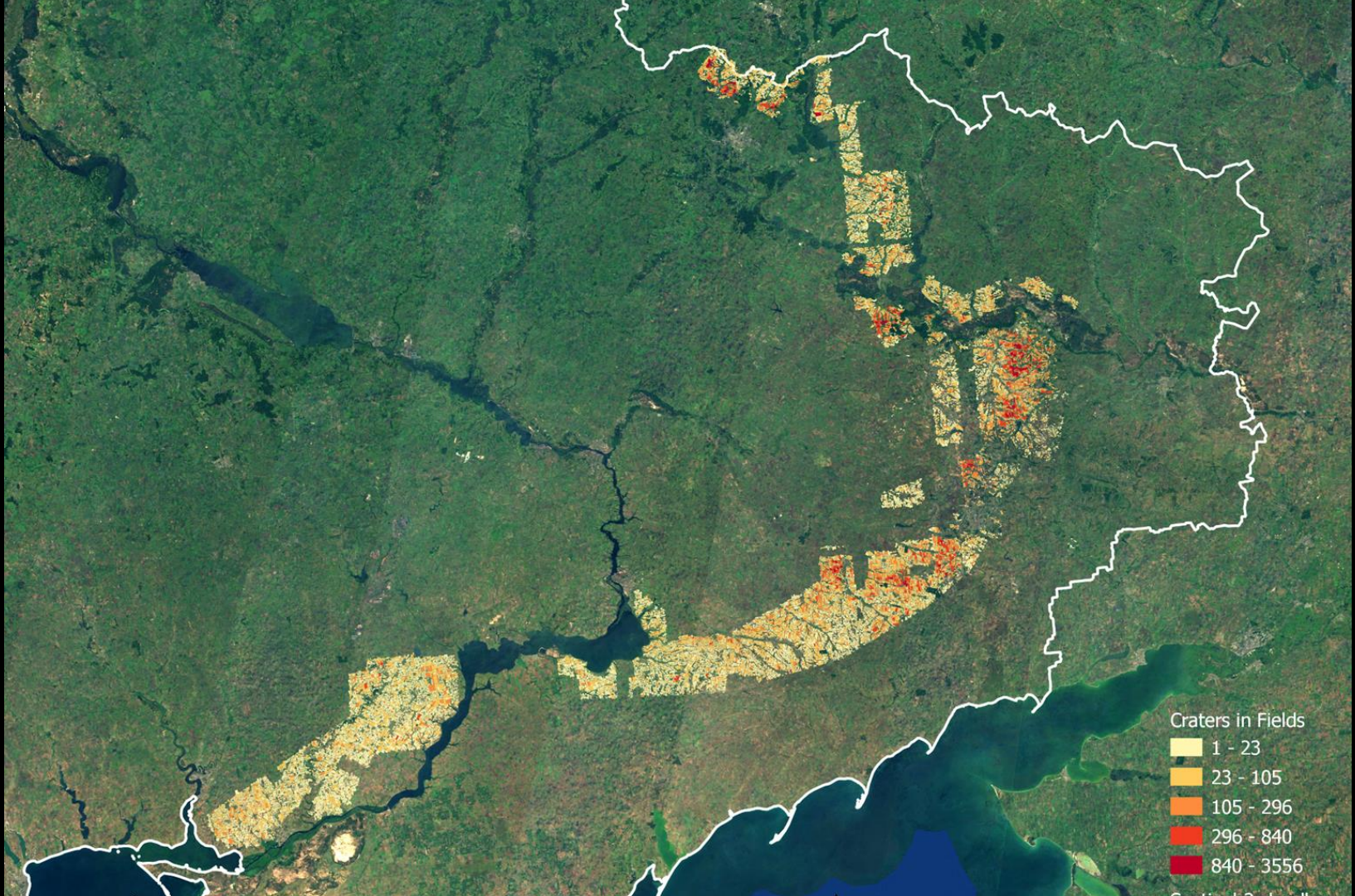
Abandoned land
Russian Fortifications

- Cropland abandonment from NASA Harvest monitoring
- Not all shelled fields are abandoned - with high risks being taken in hazardous areas
- Open source fortification maps*





Brady Africk, 2023





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Detection and mapping of artillery craters with very high spatial resolution satellite imagery and deep learning

Erik C. Duncan ^{a,b,1}, Sergii Skakun ^{a,c,*}, Ankit Kariryaa ^{b,d}, Alexander V. Prishchepov ^{b,1}

^a Department of Geographical Sciences, University of Maryland, College Park, MD, USA

^b Department of Geosciences and Natural Resource Management (IGN), University of Copenhagen, Copenhagen, Denmark

^c College of Information Studies (iSchool), University of Maryland, College Park, MD, USA

^d Department of Computer Science (DIKU), University of Copenhagen, Copenhagen, Denmark

Special issue “Land Cover and Land Use Change in Conflicted Societies” (Eds. H. Yin, X.-P. Song)

Questions?

Contact information

Erik C. Duncan

ecduncan@umd.edu